

## CLAIMS

I claim:

1 A cryosurgical instrument for ablation of endocardiac tissue, comprising:  
2 a source of a gaseous primary refrigerant, said source providing said primary  
3 refrigerant at a temperature above the critical temperature of said primary  
4 refrigerant;  
5 a source of a liquid secondary refrigerant, said secondary refrigerant having a critical  
6 temperature higher than said critical temperature of said primary refrigerant;  
7 a secondary expansion element connected to receive said liquid secondary  
8 refrigerant, said secondary expansion element being constructed to vaporize  
9 and expand said secondary refrigerant to a temperature below said critical  
10 temperature of said primary refrigerant;  
11 a primary-to-secondary heat exchanger having a primary refrigerant flow path  
12 connected to receive said gaseous primary refrigerant, and a secondary  
13 refrigerant flow path connected to receive said vaporized and expanded  
14 secondary refrigerant from said secondary expansion element, said heat  
15 exchanger being constructed to cool and liquefy said primary refrigerant;  
16 a primary expansion element connected to receive said liquid primary refrigerant  
17 from said heat exchanger, said primary expansion element being constructed  
18 to vaporize and expand said primary refrigerant to a selected cryogenic  
19 temperature; and  
20 a cryoablation heat transfer element connected to receive said vaporized and  
21 expanded primary refrigerant.

1 2. A cryosurgical instrument as recited in claim 1, further comprising a flexible  
2 coaxial catheter connected at a proximal end to said primary-to-secondary heat exchanger,  
3 said coaxial catheter having an outer low pressure tube and an inner high pressure tube, said  
4 primary expansion element and said heat transfer element being located near a distal end of  
5 said flexible catheter.

1 3. A cryosurgical instrument as recited in claim 2, wherein:  
2 said outer tube of said coaxial catheter is constructed of pebax polymer; and  
3 said inner tube of said coaxial catheter is constructed of polyimide polymer.

1 4. A cryosurgical instrument as recited in claim 1, further comprising a  
2 compressor unit connected to receive said gaseous secondary refrigerant from said heat  
3 exchanger and to repressurize, liquefy, and return said secondary refrigerant to said  
4 secondary expansion element.

1 5. A cryosurgical instrument as recited in claim 1, further comprising a vent  
2 path connected to receive said gaseous secondary refrigerant from said heat exchanger.

1 6. A cryosurgical instrument as recited in claim 1, further comprising a  
2 compressor unit connected to collect said gaseous primary refrigerant returning from said  
3 heat transfer element.

1 7. A cryosurgical instrument as recited in claim 1, further comprising a vent  
2 path connected to receive said gaseous primary refrigerant returning from said heat transfer  
3 element.

1 8. A cryosurgical instrument as recited in claim 1, wherein said primary  
2 refrigerant has a critical temperature below about 22° C, and said secondary refrigerant has a  
3 critical temperature above about 22° C.

1 9. A cryosurgical instrument as recited in claim 1, wherein said primary  
2 refrigerant comprises SUVA-95, and said secondary refrigerant comprises AZ-20.

10. A cryosurgical instrument for ablation of endocardiac tissue, comprising:

- a source of a gaseous primary refrigerant, said source providing said primary refrigerant at a temperature above the critical temperature of said primary refrigerant;
- a compressor unit constructed to provide a liquid secondary refrigerant, said secondary refrigerant having a critical temperature higher than said critical temperature of said primary refrigerant;
- a secondary expansion element connected to receive said liquid secondary refrigerant, said secondary expansion element being constructed to vaporize and expand said secondary refrigerant to a temperature below said critical temperature of said primary refrigerant;
- a primary-to-secondary heat exchanger having a primary refrigerant flow path connected to receive said gaseous primary refrigerant, and a secondary refrigerant flow path connected to receive said vaporized and expanded secondary refrigerant from said secondary expansion element, said heat exchanger being constructed to cool and liquefy said primary refrigerant;
- a secondary refrigerant return path connected to receive said gaseous secondary refrigerant returning from said heat exchanger and to conduct said gaseous secondary refrigerant to an inlet of said compressor unit;
- a primary expansion element connected to receive said liquid primary refrigerant from said heat exchanger, said primary expansion element being constructed to vaporize and expand said primary refrigerant to a selected cryogenic temperature;
- a cryoablation heat transfer element connected to receive said vaporized and expanded primary refrigerant;
- a flexible coaxial catheter connected at a proximal end to said primary-to-secondary heat exchanger, said coaxial catheter having an outer low pressure tube and an inner high pressure tube, said primary expansion element and said heat transfer element being located near a distal end of said flexible catheter; and,

30 a vent path connected to receive said gaseous primary refrigerant returning from said  
31 heat transfer element.

1 11. A method for cooling a cryoprobe cold tip for ablation of endocardiac tissue,  
2 said method comprising:

3 providing a gaseous primary refrigerant at a temperature above the critical  
4 temperature of said primary refrigerant;

5 providing a liquid secondary refrigerant, said secondary refrigerant having a critical  
6 temperature higher than said critical temperature of said primary refrigerant;

7 providing a primary-to-secondary heat exchanger having a primary refrigerant flow  
8 path and a secondary refrigerant flow path;

9 flowing said gaseous primary refrigerant through said primary refrigerant flow path  
10 of said heat exchanger;

11 flowing said liquid secondary refrigerant through a secondary expansion element to  
12 thereby vaporize and expand said secondary refrigerant to a temperature  
13 below said critical temperature of said primary refrigerant;

14 flowing said vaporized and expanded secondary refrigerant from said secondary  
15 expansion element through said secondary refrigerant flow path of said heat  
16 exchanger to cool and liquefy said primary refrigerant;

17 flowing said liquid primary refrigerant through a primary expansion element to  
18 thereby vaporize and expand said primary refrigerant to a selected cryogenic  
19 temperature; and

20 exposing said cold tip to said vaporized and expanded primary refrigerant.

1 12. A method as recited in claim 11, further comprising:

2 compressing and condensing said gaseous secondary refrigerant exiting from said  
3 heat exchanger and returning said secondary refrigerant to said secondary  
4 expansion element; and

5 venting said gaseous primary refrigerant exiting from said cold tip.

13. A method for cryogenic ablation of endocardiac tissue, comprising:  
providing a primary refrigerant at a temperature above the critical temperature of said  
primary refrigerant;  
providing a liquid secondary refrigerant having a critical temperature higher than said  
critical temperature of said primary refrigerant;  
providing a secondary expansion element, a primary-to-secondary heat exchanger, a  
flexible catheter, a heat transfer element in the distal tip of said catheter, and  
a primary expansion element near said heat transfer element;  
inserting said flexible catheter into a blood vessel of a patient;  
directing said distal tip of said catheter to a desired cardiovascular location;  
vaporizing and expanding said secondary refrigerant, with said secondary expansion  
element, to cool said secondary refrigerant to a temperature below said  
critical temperature of said primary refrigerant;  
cooling and liquefying said primary refrigerant with said vaporized and expanded  
secondary refrigerant, in said primary-to-secondary heat exchanger;  
delivering said cooled and liquefied primary refrigerant to said primary expansion  
element near said distal tip of said catheter;  
vaporizing and expanding said primary refrigerant, with said primary expansion  
element, to further cool said primary refrigerant; and  
cooling said heat transfer element with said vaporized and expanded primary  
refrigerant.